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14. ABSTRACT
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A TWO-PART STUDY ON THE USE OF BATHYMETRIC AND NAUTICAL MAPPING INFORMATION IN A MOVING MAP DISPLAY TO SUPPORT MINE COUNTER MEASURES OPERATIONS

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ABSTRACT

Cockpit moving map displays have been employed in the tactical air community for several years to support air-to-air and air-to-ground missions and have been shown to be excellent situational awareness (SA) tools. This study examines the potential of using the next-generation cockpit moving map display to support the difficult Mine Counter Measures (MCM) and Mine Sweeping Operations. Specifically, the Naval Research Laboratory – Stennis Space Center (NRLSSC) will leverage the Naval Air Systems Command's Tactical Aircraft Moving Map Capability (TAMMAC) digital moving map system as a demonstration platform to incorporate bathymetric and nautical map data designed to support in-flight MCM operations. Of critical importance to this project is a two-part human factors study to 1) determine MCM helicopter aircrew preferences from the various types of map data under consideration, and 2) measure and evaluate aircrew performance both with and without the moving map capability. This study is being conducted as part of NRLSSC's Generation and Exploitation of Common Environment (GECE) project that will support MCM and amphibious operations in Fleet Battle Experiment – India (FBE-I) or Kernal Blitz 2001 (KB '01).

Keywords: moving map displays; mine counter measures; bathymetry; nautical mapping; on-line surveys.

INTRODUCTION

In the 1980s, digital map systems were developed to replace the use of antiquated filmstrip readers and paper charts in aircraft cockpits. These early digital map systems provided a simple replacement of paper charts with geo-referenced, compressed, raster charts that were driven by the aircraft's inertial navigation system. This, in turn, provided the pilot with a "digital moving map". With advancements in mapping and computer technology and the advent of the Global Positioning System (GPS), the capabilities and application of digital moving maps systems have grown substantially. Digital moving map systems can integrate information from various sources to serve as an aid to navigation. They can also provide a means for enhancing mission effectiveness and situational awareness while reducing aircrew workload, if designed properly (Ruffner, et al., 1999; Ruffner and Trenchard, 1998). The aviation community (particularly the F/A-18 *Hornet* and AV-8B *Harrier*) has been the primary driver of digital map technology within the Navy.

The MCM community still operates on an outdated and rather cumbersome route survey set of procedures. The MH-53 mine hunting helicopter pilot relies on a set of survey track lines that are output from the Mine-Warfare Environmental Decisions Aids Library (MEDAL) system and displayed on a 2"

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by 2" screen for navigation with no background mapping information. The sonar operator, located in the rear of the aircraft, has no situational awareness display to help identify mine-like contacts from collected acoustic imagery. While the Navy plans to equip its search and rescue (CSAR) version of the CH-60S with a moving map display system, the AMCM version of the CH-60S is not planned to be so equipped. However, the functions of the map display planned for the CH-60S CSAR have analogous counterparts in MCM. This study and demonstration seeks to: first, identify and refine the nautical mapping requirements in the MCM community; and then, demonstrate and evaluate those requirements with the mapping technology that already has been developed for Naval aviation.

BACKGROUND

Navy TAMMAC Digital Map System

NRLSSC's Moving Map Composer (MMC) team has been actively involved in the TAMMAC Integrated Product Team (IPT) at NAVAIR since 1995. TAMMAC has been designated as the common digital map for Naval aviation. Therefore, TAMMAC was designed to be tailorable for different operational needs and resources. In August 1995, we performed a detailed human factors study to determine pilot preferences of various National Imagery and Mapping Agency (NIMA) digital products as potential map layers for TAMMAC (Lohrenz, et. al, 1997 and 2000). NAVAIR implemented many of our recommendations during the engineering and design phases of TAMMAC development. Several helicopter platforms were included in our 1995 study (including CH-53E, H-60 and UH-1N).

TAMMAC currently exploits several NIMA raster products, including Regridded Digital Terrain Elevation Data (RDTED), satellite imagery in the form of Common Image Base (CIB), and scanned aeronautical charts in the form of Compressed Arc Digitized Raster Graphics (CADRG). While these products are excellent situational awareness (SA) tools for ground-based flight, they provide limited information for shallow-water operations, such as MCM. However, all three of these *map modes* (i.e. RDTED, CIB, CADRG) have analogous counterparts in shallow-water operations.

The TAMMAC digital map system includes several baseline and growth capabilities (detailed in Williams, 1998) that may be applicable to the MCM community. TAMMAC digital map system baseline features and capabilities are listed in table 1. Several advanced display features that offer unique capabilities for enhancing mission effectiveness and situation awareness were not implemented in the baseline design but are included as growth features in the TAMMAC "road map" (table 2).

Table 1. Baseline capabilities of the TAMMAC digital map system.

Multiple Display Modes (e.g., chart, terrain elevation, scanned images)
Multiple Display Scales (e.g., 1:50,000, 1:250,000)
Selectable Map Orientation/Reference (e.g., north-up, track-up)
Overlay Symbology (e.g., ownship, waypoints, geographic point and linear features)
Dual Independent Outputs (e.g., pilot and sonar operator displays)
Dynamic Display Overlays (e.g., pre-planned/pop-up threats, elevation banding)
Zooming Capability (e.g., zoom in, zoom out)
Selectable Contour Lines Intervals (e.g., 50 feet, 100 feet)
Trend Dots (indicating aircraft position in 10, 20, and 30 seconds)

Table 2. Growth capabilities of the TAMMAC digital map system.

Terrain Awareness Warning System (TAWS)
De-clutterable Vector Map
3-D Perspective View
Dynamic Threat Rings
Picture-in Picture Inset Window
In-flight Mission Re-planning
Real-time Imagery in the Cockpit
Three Independent Channels

MCM Moving-Map Project

The Office of Naval Research (ONR) funded NRLSSC (as part of the GECE Project) in the summer of 2000 to perform a MCM map requirements study and demonstrate a moving map capability (using the results from the map requirements study) in support of MCM operations in KB'01 or FBE-I. KB'01 is currently planned for March 2001 and FBE-I is currently scheduled to take place in June 2001 off the southern California coast, and its goal is to demonstrate how new technology advances can significantly enhance future naval operations. For example, the next-generation mine hunting helicopters (CH-60S AMCM) plan to reduce the aircrew from five to two personnel. Therefore, MCM operations in the future will place a higher workload on the aircrew and require prudent design for new avionics equipment.

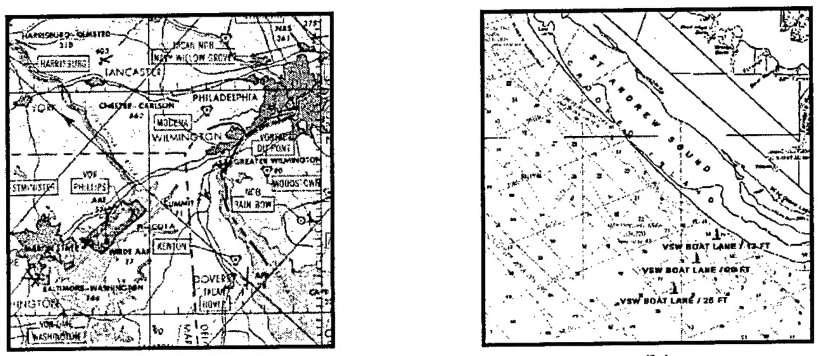
Central to the NRL GECE moving-map project is a two-part human factors study to 1) determine MCM helicopter pilot preferences for the various map data types under consideration, and 2) measure and evaluate pilot performance both with and without the moving map capability in KB'01 or FBE-I. The first part of the human factors study follows a similar format to that of our original TAMMAC study (Lohrenz, et. al, 1997). In that study, researchers displayed sample data on a simulated moving-map display and conducted one-on-one interviews at Patuxent River Naval Air Station with pilots concerning their specific map requirements and preferences. A major drawback to the earlier study was the relatively small sample size of aircrew available and the cost of allocating aircrew time and performing the study. For the MCM map requirements study, we have constructed a Web-based survey and demo in JAVA that will allow for on-line participation from pre-selected MCM squadrons. This will provide us with more statistically meaningful results and will provide for quicker analysis of the data. The aircrew questionnaire and survey database used in the original study will be tailored in the on-line survey to address specific MCM map requirements for this project. Results from this MCM map requirements survey will formulate which nautical data sets, overlays, and mission functions should be targeted for demonstration in TAMMAC for KB'01 or FBE-I.

PROCEDURE

The MMC team met with members of the AQS-20 sonar team to discuss their Concept of Operations (CONOPS) for the sonar. This information and feedback from current and former MCM aircrew helped formulate a baseline set of nautical map data from which to build the MCM map requirements survey and demo. Since TAMMAC supports four primary map modes (*Chart*, *Imagery*, *Terrain*, and *Non-geo-referenced images*), analogous data sets that are applicable to the MCM community were targeted. The nautical equivalent of CADRG is the National Oceanographic and Atmospheric Agency's (NOAA) nautical charts (figure 1). The equivalent of CIB is acoustic imagery (figure 2). Bathymetry is analogous

to the terrain map mode (figure 3). The last map mode (non geo-referenced images) will be defined from the MCM aircrew survey.

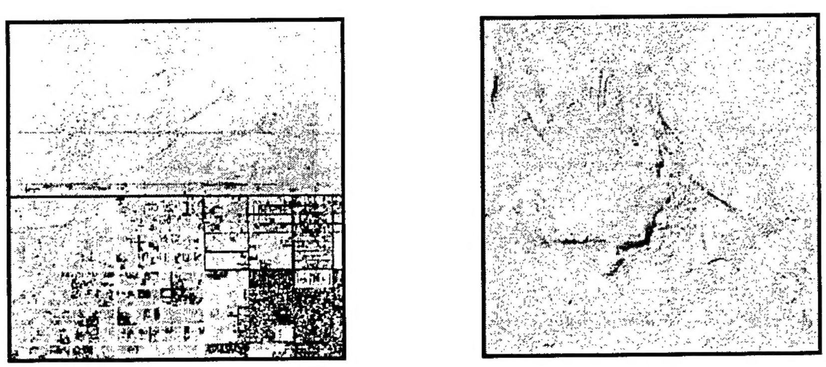
The first phase of the survey gathers MCM aircrew participants' backgrounds, flight and mission experience. Their answers to questions about their role (pilot, navigator, sonar operator, etc.) in the MCM mission lead to sample nautical map displays (figures 1-3). The participants are then questioned on the applicability of each given data type to their missions, and specifically in which phase of the mission is that data most critical. The participants are asked to rate each data type on a scale of 1 (least useful) to 5 (most useful) and provide recommendations for improvement (e.g., *What changes to the bathymetry display would you make to render a more applicable image to your mission?*).



(a) (b)

Figure 1. Chart mode examples: (a) CADRG aeronautical chart and (b) NOAA nautical chart.

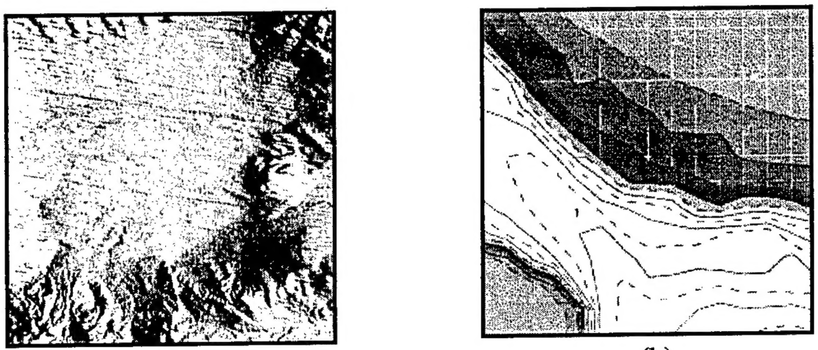
Once participants have rated each map mode individually, the participants are asked to rate the applicability of combining multiple map modes. The participants rate the sample multi-mode displays (on a scale of 1 to 5) and provide specific recommendations for implementing the various combinations of map data for their specific missions.



(a) (b)

Figure 2. Imagery mode examples: (a) CIB imagery and (b) acoustic imagery.

Finally, participants are asked to consider a display that could be derived from the real-time collected sonar and the historical (archived) map data that would be available during pre-flight (e.g., *What map information could be derived that can help you accomplish your mission in less time, with greater precision?*) Also, the survey asks what problems, which currently hinder the pilot's mission, could be addressed with a moving-map display (e.g., by heightening SA or reducing aircrew workload).



(a) (b)

Figure 3. Terrain mode examples: (a) DTED and (b) DBDBV bathymetry.

The second part of the human factors study will focus on pilot performance. Qualitative preference results can provide insight into how an aviator *expects* a given product to help him or her perform, but quantitative performance results are still needed to prove the product's contribution (if any) to the aircrew's mission. Numerous human factors studies have shown discrepancies between subjective preference ratings and objective performance measures; often, subjects do not prefer the display that produced the best performance (e.g., Merwin and Wickens, 1993). Therefore, we will measure baseline performance from post-mission analysis of KB'01 or FBE-I flights (e.g., MH-53 deviation from flight path, towed fish deviation from survey path, number of mine-like contacts correctly identified, etc.). These flights will not have the benefit of a moving-map display. Later, we will repeat the performance measurements for flights using the TAMMAC system. Our final report will document any significant differences between these performance ratings, compare the results with initial pilot preferences, and draw conclusions about whether moving-map displays such as TAMMAC can enhance MCM air missions.

DISCUSSION

In an effort to support paperless MCM operations, a detailed study and evaluation of nautical mapping information as it relates to the MCM mission is critical. While a digital moving-map system is considered to be a good SA tool (e.g. Gawron, 2000), human factors engineering (HFE) is critical for the proper design of a moving-map in the MCM arena. One of the unique problems to the MCM community is their operation in shallow water (littoral) environments. The environment can change rapidly in littoral regions. Therefore, a means of quickly analyzing, deriving, and delivering a current scene of the environment is critical. Since the environment can change so quickly, a means to provide in-situ change detection and bottom characterization from historical references to the aircrew could optimize the MCM mission. To assist the sonar operator in evaluating the real-time sonar imagery, a historical reference of known mine-like contacts could be made available via the digital moving map system. Since TAMMAC was designed to provide a great deal of flexibility to aircrew for selecting features and capabilities, TAMMAC is an excellent platform on which to demonstrate functional requirements derived from the first phase human factors study. The primary questions that will be addressed through the first phase human factors study are as follows:

- What are the <u>most critical</u> navigational and MCM <u>operational tasks</u> that would benefit from a digital moving map?
- How can TAMMAC capabilities be used to support MCM needs?

- How do we define, measure, and evaluate workload and SA for MCM mission-specific digital moving map tasks?
- How do we apply HFE principles and guidelines to best design and select TAMMAC capabilities for the MCM community?

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